COPY

FROM PERMIT APPLICATION
THOMAS #1-26
(MI-133-1I-0002)

APPENDIX A

INJECTION TESTS
OF THOMAS 1-26 DISPOSAL WELL

REPORT ON
PROPOSED BRINE DISPOSAL WELL

THOMAS 1-26
SEC. 26, T27N, R9W
OSCEOLA COUNTY, MICHIGAN

FOR

PPG INDUSTRIES, INC.
DENVER, COLORADO

BY

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TULSA, OKLAHOMA

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INDEX

INTRODUCTION

PPG Industries, Inc. (PPG) has discovered significant potash bearing deposits in an area of Mecosta and Osceola Counties. PPG desires to evaluate the recovery of this potash by solution mining methods.

The solution mining process requires the injection of water to dissolve the potash. The potash laden water (brine) is then brought to the surface so the potash can be recovered. To establish the feasibility of developing commercial potash operations, PPG is installing a small scale test facility. During the test of solution mining of potash, waste brine will be produced.

The most environmentally acceptable method for disposing of waste brine is underground injection into a strata that does not contain useable waters. This document is a report on the reentry of a dry hole exploratory well, the Thomas 1-26, and the completion and testing for conversion to a brine disposal well.

SUMMARY AND CONCLUSIONS

1. Thomas 1-26 was reentered May 6, 1985 and recompleted as a brine disposal well in the Reed City Dolomite.

2. Injection tests were made by pumping treated water into the Reed City Dolomite at rates to 28 bbls per minute (1,176 gallons per minute) at a surface pressure of 2,960 psi. After deduction of calculated friction losses of 38 psi within the well, the pressure at the top perforation in the Reed City Dolomite, while injecting treated fresh water, was 4,647 psi.

3. The injection tests were made to a pressure of 4,647 psi at the top perforation of the Reed City Dolomite without parting or fracturing of the formation. This is equivalent to a pressure gradient of 1.18 psi per foot of depth. This test indicates that brine can be safety injected to a pressure equivalent to this gradient.

4. Well tests and the NL McCullough Cement Bond Log indicate that the well is secure so that injected brine will be confined to the Reed City Dolomite.

Spotted 750 gallons of 20 percent hydrochloric acid across perforations (acid spotted by Halliburton, Inc.).

Displaced acid into Reed City Dolomite and made injectivity tests with treated water at 5 to 28 bbls. per minute (210 to 1,176 gallons per minute) (pumping performed by Halliburton).

A schematic of the final proposed well completion is shown in Figure 1.

PERFORATIONS

The 9-5/8" casing was perforated by NL McCullough opposite the Reed City Dolomite at the following depths based on the McCullough Gamma Ray-Neutron Log of 5/13/85:

Run No. 1: Perforations 4,080, 4,079, 4,078, 4,077, 4,076, 4,075, 4,074, 4,073, 4,072, 4,071, 4,070, 4,069, 4,068, 4,067, 4,066, 4,065, 4,064 (17 holes).

Run No. 2: Perforations 4,059, 4,058, 4,057, 4,056, 4,051, 4,050, 4.049, 4,047, 4,046 (9 holes).

Run No. 3: Perforations 4,043, 4,039, 4,038, 4,037, 4,036, 4,035, 4,034, 4,033, 4,032, 4,031, 4,030, 4,029, 4,028, 4,027, 4,026 (15 holes).

Run No. 4: Perforations 4,022, 4,021, 4,020, 4,017, 4,016, 4,015, 4,014, 4,013, 4,012, 4,011, 4,007 (11 holes).

Run No. 5: Perforations 4,001, 4,000, 3,999, 3,998, 3,997, 3,996, 3,995 (7 holes).

Run No. 6: Perforations 3,972, 3,971, 3,970 (3 holes).

Run No. 7: Perforations 3,959, 3,958, 3,957, 3,956, 3,955, 3,951, 3,950, 3,949 (8 holes).

Run No. 8: Perforations 3,941, 3,936, 3,935, 3,930, 3,929, 3,928 (6 holes).

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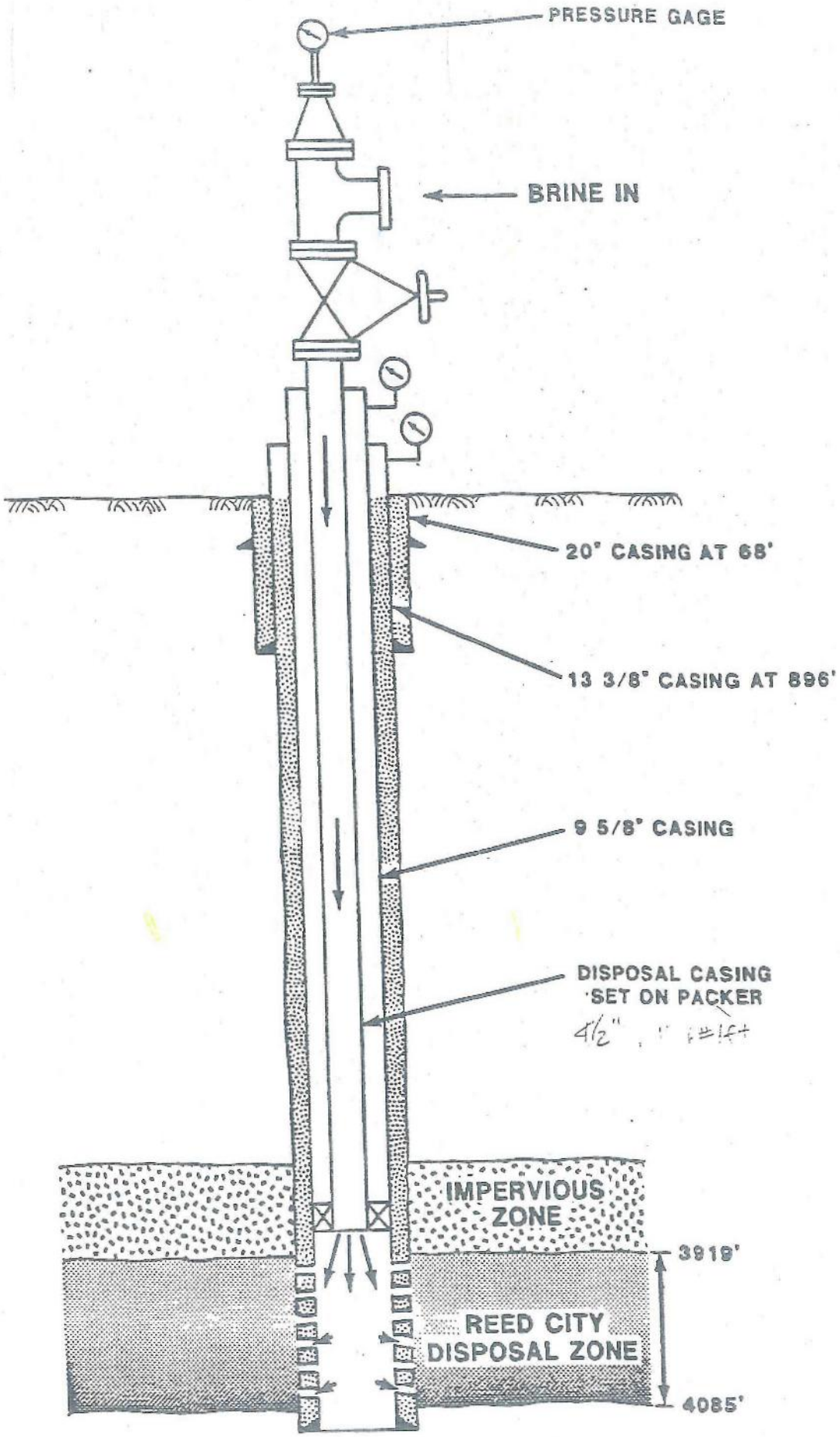
DISPOSAL WELL



DISCUSSION OF . .ECTION TESTS

The injection tests were made with water treated with two percent potassium chloride and weighing 8.45 lbs/gallon. Injection was down the well via the 9-5/8" 40 lb/ft. N-80 casing.

Figure 2 is a graph of surface injection pressure vs. water injection rates and Figure 3 is a graph of bottom hole pressure vs. water injection rates. For Figure 3, the bottom hole pressure is calculated at a depth of the top perforation, 3,928 feet, into the Reed City Dolomite. The bottom hole pressure was arrived at by adding the pressure due to the weight of the water column to a depth of 3,928 feet and the surface injection pressure and deducting the friction losses in the 9-5/8" casing.

The data for Figures 2 and 3 are as follows:

Injection Rate Bbls/Min.	Surface Pressure psi.	Pressure Due to Weight of Water Column - psi.	Calculated Friction Pressure - psi.	Bottom Hole Pressure psi.
5	470	1,725	1	2,194
10	860	1,725	4	2,581
14	1,260	1,725	8	2,977
16	1,470	1,725	10	3,185
18	1,740	1,725	17	3,448
21	2,120	1,725	22	3,823
23	2,350	1,725	26	4,049
25	2,600	1,725	31	4,294
28	2,960	1,725	38	4,647

From analyzing the graphs, it is evident that the parting or fracture pressure of the formation was not reached during these tests. Had the formation fracture pressure been exceeded, there would have been a rapid increase in the injection rate with only a small increase in injection pressure.

These tests indicate that a disposal pressure of 4,647 psi., applied to the Reed City Dolomite, will not fracture the formation and that brine will be contained within the Reed City Dolomite at that pressure.

TEST ONLY FOR REED CITY DOLOMITE
NO OTHER FORMATION.

FIGURE 2

SURFACE PRESSURE VS WATER INJECTION RATE

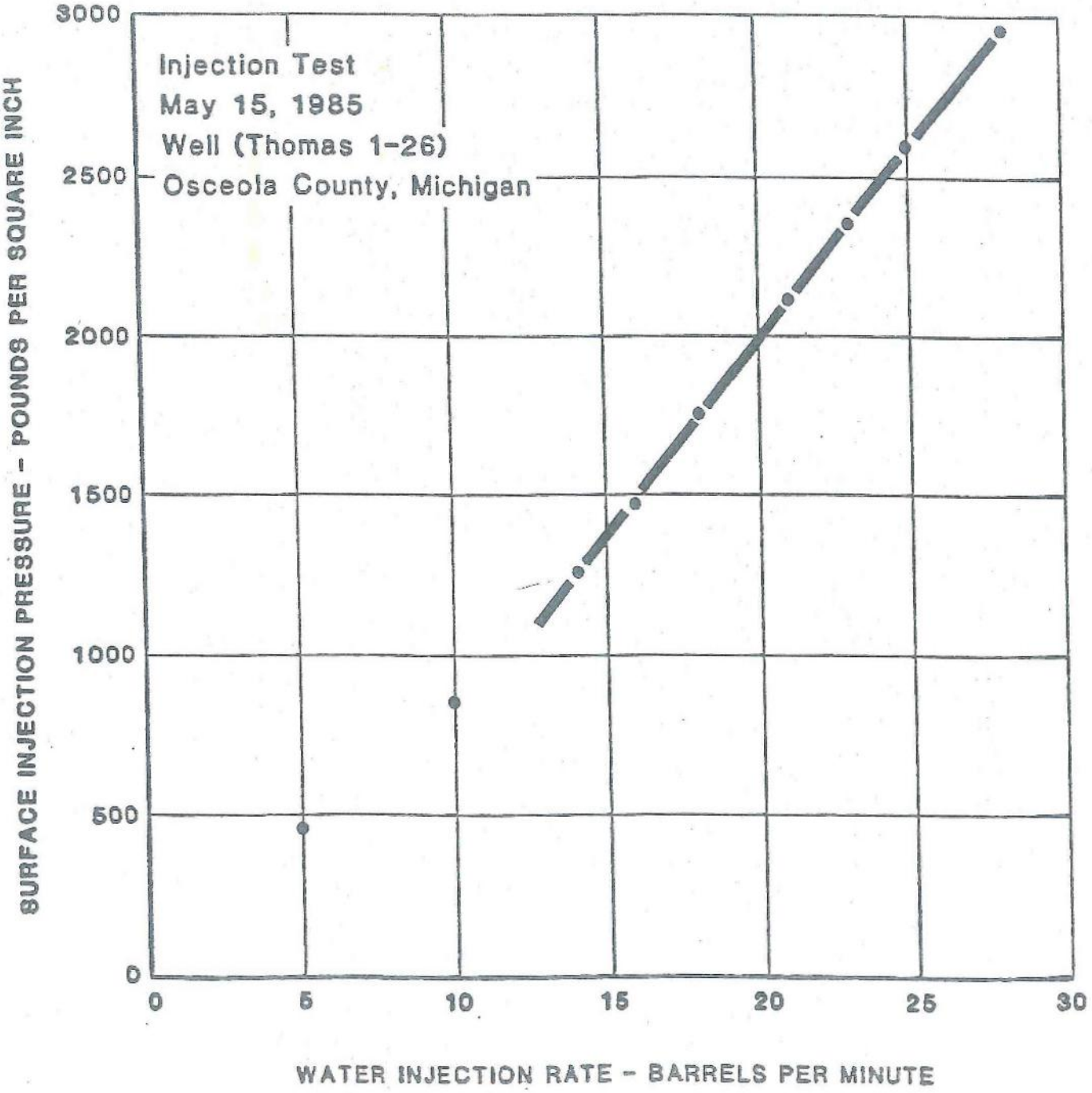
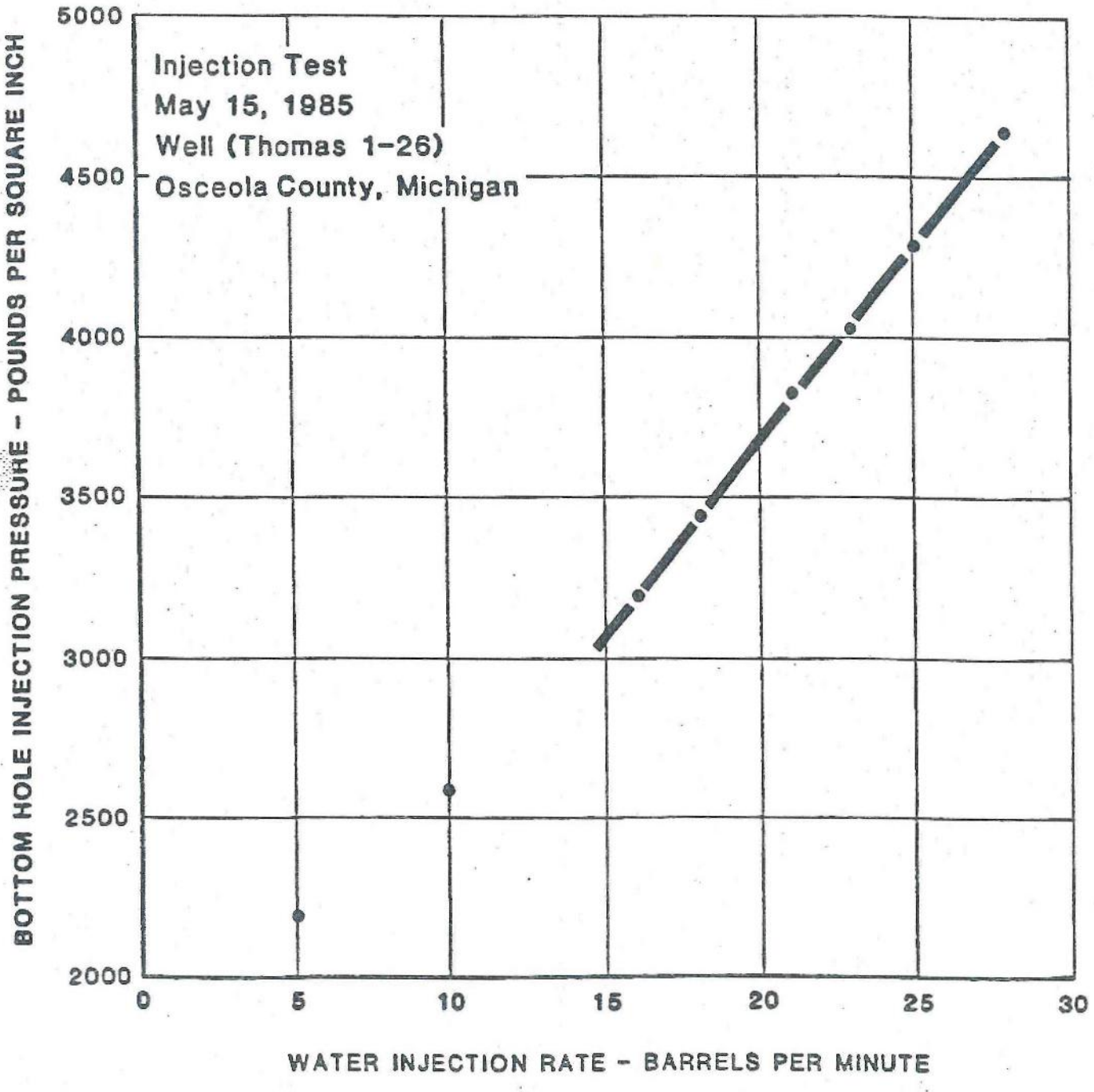


FIGURE 3

BOTTOM HOLE PRESSURE VS WATER INJECTION RATE



INJECTION TEST PROCEDURE

After the reentry, injection tests were made by pumping into the Reed City Dolomite. Following is a description of the test procedures:

Drill pipe was run open ended to below the bottom of the perforations of the Reed City Dolomite. Perforations were from 3,928 feet to 4,080 feet and totaled 76 perforations.

Two thousand barrels of water in surface tankage were treated to make a two percent potassium chloride solution. Weight of the treated water was 8.45 pounds per gallon. → SG = 1.014

FRESH WATER = 8.333 lb/gal

Seven hundred and fifty gallons of 20 percent hydrochloric acid was pumped into the drill pipe by Halliburton and displaced with treated water so that acid was spotted across the perforations.

The drill pipe was pulled from the hole.

The wellhead was assembled and tested.

Halliburton pressure recorder was calibrated by use of a dead weight tester.

Halliburton displaced the acid into the formation by pumping treated water and gradually increased their pump rate to obtain a series of flow rates while noting the surface injection pressure. The rates were first measured with a four inch turbine meter but the meter failed at high rates. Another series of pump tests were made using a second Halliburton turbine meter. The second series of injection tests were tabulated as follows:

Rate		Surface Injection Pressure psi
Bbls/Min.	Gal/Min.	
5	210	470
10	420	860
14	588	1,260
16	672	1,470
18	756	1,740
21	882	2,120
23	966	2,350
25	1,050	2,600
28	1,176	2,960

CALCULATION OF BOTTOM HOLE PRESSURE APPLIED TO THE REED CITY DOLOMITE DURING THE INJECTION TEST

The bottom hole pressure (BHP) opposite the Reed City Dolomite during the injection tests would be: the surface injection pressure (SIP) plus the pressure due to the weight of the water column to the depth of the Reed City Dolomite less the friction pressure losses (f) in the 9-5/8" casing.

BHP = (SIP) + Pressure due to water column - (f)

The surface injection pressure and flow rates were read at the surface during the injection testing.

The pressure due to the weight of the water column would be the weight of water per square inch at the depth of the top Reed City perforation of 3,928 feet.

Calculations:

Weight of test water = 8.45 lbs. per gallon, then weight of water per foot of depth = 0.4394 psi/foot.

Pressure due to weight of water at the depth of the top Reed City perforation.

3,928' x 0.4394 psi/ft. = 1,725 psi.

The friction losses (f) in the 9-5/8" casing during the injection test were calculated by using the Hazen-Williams formula for liquid flow:

$$= \frac{3{,}928'}{5{,}280'} \left[\frac{162.04\ Q\ g^{0.54}}{C\ d^{2.63}}\right]^{1.85}$$

Where Q represents barrels of liquid per hour;

g = specific gravity of liquid

C = a factor to allow for pipe roughness and viscosity of the liquid. For these tests a C of 125 was used.

d = internal diameter of the casing in inches. For the 9-5/8" 40# N-80 casing in these tests, the d was 8.825 inches.

The ratio 3,928/5,280 is to correct to the depth of the top perforations. The formula is set up to give friction losses in psi per mile.

DISCUSSION ON NL MC CULLOUGH CEMENT BOND LOG → LOG PERFORMED BEFORE INJECTION TEST. LOG NOT AN EVALUATION OF STRESS ON CASING AND CEMENT.

The log was made on May 13, 1985 and the interval logged was from the plugback total depth (effective total depth) of 4,432 feet to the surface. The liquid level in the well was at 368 feet and no data was obtained above that depth.

Based on interpretation of the cement bond long, good cement bonding exists above and below the Reed City Dolomite. This bonding is adequate to isolate the Reed City Dolomite; therefore, brine injected into the Reed City Dolomite cannot migrate into any other formation.

A general interpretation of the log is as follows:

Interval:

4,428 feet - 3,800 feet	good to fair cement bonding;
3,800 feet - 3,000 feet	fair cement bonding;
3,000 feet - 2,290 feet	poor cement bonding;
2,290 feet - 750 feet	good cement bonding; and
750 feet - 368 feet	intervals of good cement bonding interspersed with intervals of poor cement bonding.

A copy of the log is included in the pocket on page 13.

DISCUSSION OF NL MC CULLOUGH GAMMA RAY - NEUTRON LOG

The log was made on May 13, 1985 and the interval logged was from 4,428 feet to the surface. A casing collar log (CCL) was run simultaneously with the Gamma Ray - Neutron log (GR-N) so that the 9-5/8" casing collars could be located exactly in relation to the rock strata.

The primary purpose of the log was to provide correlation with previously ran logs so that depth control was exact for proper placement of the perforations into the Reed City Dolomite.

A casing collar locator was attached to the perforating gun on each of the eight trips into the well for perforating. By correlating the casing collars identified by the collar locator on the perforating trip with the collars identified by the GR-N-CCL log the perforations could be made at exactly the correct intervals of the Reed City Dolomite.

A copy of the log is included in the pocket on page 14.

The GR-N identified depths of formations by log measurements as follows:

Reed City Anhydrite	3,909 feet - 3,917 feet
Reed City Dolomite	3,917 feet - 4,085 feet
Uppermost Detroit River Anhydrite	4,085 feet - 4,145 feet

The anhydrite above and below the Reed City Dolomite are impermeable strata and will not allow brine to escape from its Reed City Dolomite.

Log depths are made by steel line measurement.